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FORM PTO-1390 US DEPARTMENT OF COMMERCE REV. 5-93PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEYS DOCKET NUMBER **P01,0284** U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 09/937878
INTERNATIONAL APPLICATION NO. **PCT/DE00/00608**	INTERNATIONAL FILING DATE **01 MARCH 2000**	PRIORITY DATE CLAIMED **31 MARCH 1999**

TITLE OF INVENTION

METHOD AND ARRANGEMENT FOR MEASURING DISTRIBUTION FUNCTIONS FOR DETERMINING THE SIGNAL QUALITY IN OPTICAL TRANSMISSION SYSTEMS

APPLICANT(S) FOR DO/EO/US

Oliver BLECK, et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report, References)**.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included. **(SEE ATTACHED ENVELOPE)**
13. ☒ Amendment "A" Prior to Action and Appendix "A".
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☒ A substitute specification and substitute specification mark-up.
15. ☒ A change of address letter attached to the Declaration.
16. ☒ Other items or information:
    a. ☒ Submission of Drawings and drawing changes
    b. ☒ COPY OF THE INTERNATIONAL SEARCH REPORT
    b. ☒ EXPRESS MAIL #EL 843744135 US dated October 1, 2001

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 09/937878	INTERNATIONAL APPLICATION NO PCT/DE00/00608	ATTORNEY'S DOCKET NUMBER P01,0284

				CALCULATIONS	PTO USE ONLY
17. ☒ The following fees are submitted: **BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5):** Search Report has been prepared by the EPO or JPO $890.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) $690.00 No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2) $710.00 Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO $1000.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $ 100.00					
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F.R. 1 492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	27 - 20 =	7	X $ 18.00	$ 126.00	
Independent Claims	04 - 3 =	1	X $ 84.00	$ 84.00	
Multiple Dependent Claims			$280.00 +	$	
TOTAL OF ABOVE CALCULATIONS =				$ 1100.00	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28)				$	
SUBTOTAL =				$ 1100.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 1100.00	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property +					
TOTAL FEES ENCLOSED =				$ 1100.00	
				Amount to be refunded	$
				charged	$

a. ☒ A check in the amount of $ 1100.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. __________ in the amount of $ _______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 50-1519. **A duplicate copy of this sheet is enclosed.**

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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Registration Number

09/937878
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BOX PCT
IN THE UNITED STATES DESIGNATED/ELECTED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY--CHAPTER II

PRELIMINARY AMENDMENT A
PRIOR TO ACTION

APPLICANT(S):	Oliver BLECK, et al.
ATTORNEY DOCKET NO.:	P01,0284
INTERNATIONAL APPLICATION NO:	PCT/DE00/00608
INTERNATIONAL FILING DATE:	01 MARCH 2000

INVENTION: METHOD AND ARRANGEMENT FOR MEASURING DISTRIBUTION FUNCTIONS FOR DETERMINING THE SIGNAL QUALITY IN OPTICAL TRANSMISSION SYSTEMS

Assistant Commissioner for Patents,
Washington D.C. 20231

Sir:

Applicants herewith amend the above-referenced PCT application, and request entry of the Amendment prior to examination on the United States Examination Phase.

IN THE CLAIMS:

On amended page 12:

replace line 1 with --WHAT IS CLAIMED IS:--;

Please replace original claims 1-13 with the following rewritten claims 1-13, referring to the mark-ups in Appendix A.

1. (Amended) A method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of:

sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values;

additionally sampling said optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case said second threshold value is varied, producing second sampling values;

comparing respective said first sampling values with said second sampling values, producing comparison values;

integrating or summating said comparison values to produce, for each measuring interval, a summated comparison value;

storing said summated comparison values;

determining a distribution function of said comparison values as a function of said second variable threshold value after an adequate number of said measuring intervals; and

improving said signal quality or optimizing said optical transmission system utilizing said distribution function.

2. (Amended) A method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of:

sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values;

additionally sampling said optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case said second threshold value is varied, producing second sampling values;

determining, for each said measuring interval, a first summated value in said measuring channel by integrating sampled logical zeros or ones;

storing said first summated values;

determining, for each measuring interval, a number of bits received as a summated bit value;

storing said summated bit values;

determining a probability function, after an adequate number of said measuring intervals, as a function of said variable second threshold value for an occurrence of a binary state from said stored first summated values and associated said summated bit values; and

improving said signal quality or optimizing said optical transmission system utilizing said distribution function.

3. (Amended) A method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of:

sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values;

additionally sampling said optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case said second threshold value is varied, producing second sampling values;

determining, for each said measuring interval, a first summated value in said measuring channel by integrating sampled logical zeros or ones;

storing said first summated values;

determining, for each measuring interval, a second summated value in said working channel by integrating received zeros or ones;

storing said second summated values;

determining a probability function, after an adequate number of said measuring intervals, as a function of said variable second threshold value for an occurrence of a binary state from said stored first summated values and associated said second summated values; and

improving said signal quality or optimizing said optical transmission system utilizing said distribution function.

4. (Amended) The method as claimed in claim 3, further comprising the steps of:

forming, after each measuring interval, a difference value between said first summated value determined in said measuring channel, and said second summated value determined in the working channel;

storing said difference values for said measuring intervals; and

determining, from said difference values, a probability function for and occurrence of logical sampled values.

5. (Amended) The method as claimed in claim 4, further comprising the step of:

determining a probability distribution for an occurrence of logical sampled values that considers said second summated values in the working channel or said summated value of the bits respectively assessed during a measuring interval.

6. (Amended) The method as claimed in claim 1, wherein measuring intervals of different lengths are used.

7. (Amended) The method as claimed in claim 1, wherein said sampling is synchronous.

8. (Amended) The method as claimed in claim 1, wherein said sampling takes place in parallel in a plurality of measuring channels with different threshold values.

9. (Amended) The method as claimed in claim 8, wherein said sampling takes place in parallel in a plurality of measuring channels with different threshold values during only one measuring interval.

10. (Amended) The method as claimed in claim 1, further comprising the step of changing a sampling instant in the measuring channel after each measuring interval.

11. (Amended) The method as claimed in claim 1, further comprising the steps of:

measuring probability distributions with differently set dispersion values;

storing measurement results; and

obtaining, from said stored measurement results, an at least approximately optimum value for dispersion compensation.

12. (Amended) The method as claimed in claim 1, further comprising the steps of:

determining a probability density distribution; and

deriving criteria for an assessment or optimization of signal quality are derived from said probability density distribution.

13. (Amended) An arrangement for measuring the signal quality of WDM signals, comprising:

a channel selection circuit, with which a WDM channel is in each case selected;

an optoelectronic conversion device that converts an optical signal; and

a measuring device that is fed a signal after conversion by said optoelectronic conversion device that utilizes a probability distribution and determines a signal-to-noise ration as a main signal parameter.

Please add the following new claims 14-27.

14. (New) The method as claimed in claim 2, wherein measuring intervals of different lengths are used.

15. (New) The method as claimed in claim 3, wherein measuring intervals of different lengths are used.

16. (New) The method as claimed in claim 2, wherein said sampling is synchronous.

17. (New) The method as claimed in claim 3, wherein said sampling is synchronous.

18. (New) The method as claimed in claim 2, wherein said sampling takes place in parallel in a plurality of measuring channels with different threshold values.

19. (New) The method as claimed in claim 3, wherein said sampling takes place in parallel in a plurality of measuring channels with different threshold values.

20. (New) The method as claimed in claim 18, wherein said sampling takes place in parallel in a plurality of measuring channels with different threshold values during only one measuring interval.

21. (New) The method as claimed in claim 19, wherein said sampling takes place in parallel in a plurality of measuring channels with different threshold values during only one measuring interval.

22. (New) The method as claimed in claim 2, further comprising the step of changing a sampling instant in the measuring channel after each measuring interval.

23. (New) The method as claimed in claim 3, further comprising the step of changing a sampling instant in the measuring channel after each measuring interval.

24. (New) The method as claimed in claim 2, further comprising the steps of:
measuring probability distributions with differently set dispersion values;
storing measurement results; and
obtaining, from said stored measurement results, an at least approximately optimum value for dispersion compensation.

25. (New) The method as claimed in claim 3, further comprising the steps of:
measuring probability distributions with differently set dispersion values;
storing measurement results; and
obtaining, from said stored measurement results, an at least approximately optimum value for dispersion compensation.

26. (New) The method as claimed in claim 2, further comprising the steps of:
determining a probability density distribution; and
deriving criteria for an assessment or optimization of signal quality are derived from said probability density distribution.

27. (New) The method as claimed in claim 3, further comprising the steps of:

determining a probability density distribution; and

deriving criteria for an assessment or optimization of signal quality are derived from said probability density distribution.

REMARKS

The present Amendment revises the specification and claims to conform to United States patent practice, before examination of the present PCT application in the United States National Examination Phase. Pursuant to 37 CFR 1.125 (b), applicants have concurrently submitted a substitute specification, excluding the claims, and provided a marked-up copy. All of the changes are editorial and applicant believes no new matter is added thereby. The amendment, addition, and/or cancellation of claims is not intended to be a surrender of any of the subject matter of those claims.

Early examination on the merits is respectfully requested.

Submitted by,

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Appendix A
Mark Ups for Claim Amendments

1. **(Amended)** A method of measuring a distribution function for determining [~~the~~]**a** signal quality in optical transmission systems, [~~in which~~]**comprising the steps of:**

sampling an optical binary signal[~~ is sampled~~] in a working channel with a first threshold value[~~ (Sw) and is ~~]**, producing first sampling values;**

additionally [~~sampled~~]**sampling said optical binary signal** in a measuring channel with a second threshold value[~~ (Sv), then the sampled bits are compared and the comparison values (VD) derived from this are integrated, characterized in that the binary signal (BS) is sampled in the measuring channel~~] during a plurality of measuring intervals[~~,~~] **in which** in each case [~~with a~~]**said second threshold value is** varied[~~ second threshold value (Sv)~~], [~~in that~~]**producing second sampling values;**

comparing respective said first sampling values with said second sampling values, producing comparison values;

integrating or summating said comparison values to produce, for each measuring interval**,** a summated comparison value[~~ (IW) is determined by integration of the comparison values (VD), in that the~~]**;**

storing said summated comparison values[~~ (IW) are stored and in that,~~]**;**

determining a distribution function of said comparison values as a function of said second variable threshold value after an adequate number of **said** measuring intervals[~~, the~~]**; and**

improving said signal quality or optimizing said optical transmission system utilizing said distribution function[~~ (V(s)) of the comparison values (VD) is determined as a function of the variable threshold value (Sv)~~].

2. **(Amended)** A method of measuring a distribution function for determining [~~the~~]**a** signal quality in optical transmission systems, [~~in which~~]**comprising the steps of:**

sampling an optical binary signal[~~ (BS) is sampled~~] in a working channel with a first threshold value[~~ (Sw) and is sampled~~]**, producing first sampling values;**

additionally sampling said optical binary signal in a measuring channel with a second threshold value[~~ (Sv), characterized in that the binary signal (BS) is sampled in the measuring channel~~] during a plurality of measuring intervals[~~,~~]**in which** in each case [~~with a~~]**said second threshold value is** varied**, producing** second [~~threshold~~]**sampling** values[~~ (Sv), in that~~]**;**

determining, for each **said** measuring interval, a first summated value [~~(IV) is determined~~]in [~~the~~]**said** measuring channel by [~~integration of the~~]**integrating** sampled logical zeros or ones[~~, in that the~~]**;**

storing said first summated values[~~ (IV) are stored, in that~~]**;**

determining, for each measuring interval, [~~the~~]**a** number of bits received [~~is determined~~]as a summated bit value[~~ (IB) and in that the~~]**;**

storing said summated bit values[~~ (IB) are stored and~~]**;**

[~~in that~~]**determining a probability function**, after an adequate number of **said** measuring intervals, [~~the probability function (WV(Sv), WW(Sv)) is determined~~]as a function of [~~the~~]**said** variable **second** threshold value [~~(Sv)~~]for [~~the~~]**an** occurrence of a binary state from [~~the~~]**said** stored first summated values[~~ (IV)~~] and associated **said** summated bit values**;** [~~(IB).~~]**and**

improving said signal quality or optimizing said optical transmission system utilizing said distribution function.

3. **(Amended)** A method of measuring a distribution function for determining [~~the~~]**a** signal quality in optical transmission systems, [~~in which~~]**comprising the steps of:**

sampling an optical binary signal[~~ (BS) is sampled~~] in a working channel with a first threshold value[~~ (Sw) and is sampled~~]**, producing first sampling values;**

additionally sampling said optical binary signal in a measuring channel with a second threshold value[~~ (Sv), characterized in that the binary signal (BS) is sampled in the measuring channel~~] during a plurality of measuring [~~intervals,~~]**intervals in which** in each case [~~with a~~]**said second threshold value is** varied**, producing** second [~~threshold value (Sv), in that~~]**sampling values;**

determining, for each **said** measuring interval, a first summated value [~~(IV) is determined~~]in [~~the~~]**said** measuring channel by [~~integration of the~~]**integrating** sampled logical zeros or ones[~~, in that the~~]**;**

storing said first summated values[~~ (IV) are stored, in that~~]**;**

determining, for each measuring interval, a second summated value [~~(IE) is determined~~]in [~~the~~]**said** working channel by [~~integration of the~~]**integrating** received zeros [~~and/~~]or ones[~~, in that the~~]**;**

storing said second summated values[~~ (IE) are stored and in that~~]**;**

determining a probability function, after an adequate number of **said** measuring intervals,[~~ the probability function (WV(Sv), WW(Sv)) is determined~~] as a function of [~~the~~]**said** variable **second** threshold value [~~(Sv)~~]for [~~the~~]**an** occurrence of a binary state from [~~the~~]**said** stored first summated values [~~(IV)~~]and **associated said** second summated values**;** [~~(IE).~~]**and**

improving said signal quality or optimizing said optical transmission system utilizing said distribution function.

4. **(Amended)** The method as claimed in claim 3, [~~characterized in that~~]**further comprising the steps of:**

forming, after each measuring interval, [~~the~~]**a** difference **value** between [~~the~~]**said** first summated value [~~(IV),~~]determined in [~~the~~]**said** measuring channel, and [~~the~~]**said** second summated value [~~(IE),~~]determined in the working channel[~~, is formed,~~]**;**

[~~in that the~~]**storing said** difference values for [~~the~~]**said** measuring intervals[~~ are buffer-stored~~]**;** and[~~ in that~~]

determining, from said difference values, a probability function [~~WD(Sv)~~]for [~~the~~]**and** occurrence of logical sampled[~~ values (0,1) is determined from the difference~~] values.

5. **(Amended)** The method as claimed in claim 4, [~~characterized in that~~]**further comprising the step of:**

determining a probability distribution [~~(WW)~~]for [~~the~~]**an** occurrence of logical sampled values [~~(0,1) is determined, taking into account the~~]**that considers said**

second summated values [~~(IE)~~]in the working channel or [~~the~~]**said** summated value[~~(IB)~~] of the bits respectively assessed during a measuring interval.

6. **(Amended)** The method as claimed in [~~one of the preceding claims, characterized in that~~]**claim 1, wherein** measuring intervals of different lengths are used.

7. **(Amended)** The method as claimed in [~~one of the preceding claims, characterized in that a~~]**claim 1, wherein said sampling is** synchronous[~~ sampling of the binary signals (BS) takes place~~].

8. **(Amended)** The method as claimed in [~~one of the preceding claims, characterized in that the~~]**claim 1, wherein said** sampling takes place in parallel in a plurality of measuring channels with different threshold values[~~ (Sv1 to Svn)~~].

9. **(Amended)** The method as claimed in claim 8, [~~characterized in that the~~]**wherein said** sampling takes place in parallel in a plurality of measuring channels with different threshold values[~~ (Sv1 to Svn)~~] during only one measuring interval.

10. **(Amended)** The method as claimed in [~~one~~]**claim 1, further comprising the step** of [~~the preceding claims, characterized in that in the measuring channel the~~]**changing a** sampling instant [~~is changed~~]**in the measuring channel** after each measuring interval.

11. **(Amended)** The method as claimed in [~~one~~]**claim 1, further comprising the steps** of[~~ claims 1 to 8, characterized in that the measurements of the~~]**:**

measuring probability distributions [~~take place~~]with differently set dispersion values[~~, in that the~~]**;**

storing measurement results[~~ are buffer~~]**; and**

obtaining, from said stored [~~and in that~~]**measurement results,** an at least approximately optimum value for [~~the~~]dispersion compensation[~~ is obtained from them~~].

12. **(Amended)** The method as claimed in [~~one of claims 1 to 11, characterized in that~~]**claim 1, further comprising** the **steps of:**

determining a probability density distribution[~~ (P(S), WD(S), WDI(S)) is determined~~]**;** and

deriving criteria for [~~the~~]**an** assessment [~~and/~~]or optimization of [~~the~~]signal quality are derived from [~~it~~]**said probability density distribution**.

13. **(Amended)** An arrangement for measuring the signal quality of WDM signals, [~~characterized in that~~]**comprising:**

a channel selection circuit[~~ (10) is provided~~], with which a WDM channel is in each case selected**;**

an optoelectronic conversion device that converts an optical signal; and

a measuring device that is fed **a signal** after **conversion by said** optoelectronic conversion [~~to a measuring~~]device [~~(13), in~~]that [~~the~~]**utilizes a** probability distribution [~~is measured in a way corresponding to one of claims 1 to 11~~]and [~~in that at least the~~]**determines a** signal-to-noise [~~ratio is measured~~]**ration** as [~~the~~]**a** main signal parameter.

Document comparison done by DeltaView on Tuesday, September 25, 2001 08:31:54

This redlined draft, generated by CompareRite (TM) - The Instant Redliner, shows the differences between - original document : Q:\DOCUMENTS\YEAR 2001\P010284-BLECK\ORIGINAL SPECIFICATION.DOC and revised document: Q:\DOCUMENTS\YEAR 2001\P010284-BLECK\SUBSTITUTE SPECIFICATION X.DOC

CompareRite found 202 change(s) in the text

Deletions appear as Overstrike text surrounded by []
Additions appear as Bold-Underline text

SPECIFICATION

TITLE [~~DESCRIPTION~~]

METHOD AND ARRANGEMENT FOR MEASURING DISTRIBUTION FUNCTIONS FOR DETERMINING THE SIGNAL QUALITY IN OPTICAL TRANSMISSION SYSTEMS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The invention relates to methods for measuring distribution functions for determining the signal quality in an optical transmission systems. A suitable arrangement makes it possible to measure the statistical properties and main signal parameters. The measurement results can be used for improving the signal quality, for example**,** for optimizing the dispersion compensation.

[~~On the basis of the measurements of distribution functions, statements~~]**[0002]** **Statements** concerning the quality of a received binary signal, and consequently also the properties of the transmission system and the transmission link, can be made **based** on [~~the basis of~~] statistical evaluations **and measurements of distribution functions**. These statements can in turn be used for optimizing the system, for example**,** for setting an optimum sampling instant, **for setting** an optimum sampling threshold**,** or for dispersion compensation.

DESCRIPTION OF THE RELATED ART

[0003] **German patent document** [~~German Offenlegungsschrift~~] DE 195 04 896 A1 discloses [~~a monitoring of the~~] signal quality **monitoring** of transparent optical networks in which a random **signal** sampling [~~of a signal~~] is

performed. The random amplitude samples obtained in this way are evaluated ~~[by means of]~~ **using** a known statistical method. ~~[In an earlier patent application, application number ...]~~ **German patent document** DE 198 17 078.8~~[,]~~ **further develops** this method ~~[is further developed in that]~~ **by evaluating** only the outer edges of a probability density function derived from the measurement results ~~[are evaluated]~~. This allows**,** for example**,** the bit error rate to be estimated. However, ~~[the]~~ **this** method ~~[described here]~~ requires very fast sampling and storing capabilities.

~~[In US Patent]~~**[0004]** **United States patent number** 5,585,954 ~~[there is a description of]~~ **describes** an arrangement for measuring the error rate in the case of different decision-circuit threshold values **based** on ~~[the basis of]~~ a predetermined pseudo-random sequence, used for determining the transmission characteristic. However, the data transmission has to be interrupted for this purpose. The measured bit error rate is only conditionally suitable for establishing non-linear effects.

[0005] In a paper by Hitoshi Takashita and Naoya Henmi Optical Fiber Communication Conference (OFC) 99, San Diego, California, FJ 2-1, pp. 149 - 151, ~~[in]~~ an article ~~["A]~~ **titled "A** novel data format free bit-by-bit quasi-error monitoring method for optical transport ~~[network"]~~ **network" describes the use of** a receiving circuit with two sampling circuits which have different thresholds ~~[is used]~~. By sampling the binary signal with two different thresholds, a quasi bit error rate is measured and a direct correlation with the bit error rate is established. No further statistical statements are made.

SUMMARY OF THE INVENTION

[0006] The object of the invention is to ~~[specify]~~ **provide** measuring methods ~~[by which]~~ **for determining** distribution functions which can be statistically evaluated ~~[can be determined.]~~**.**

~~[In further subobjects, the]~~**[0007]** **Further inventive objects include providing an** application for improving the signal quality, for example**,** by optimizing the dispersion compensation, and a suitable measuring arrangement ~~[are to be specified.]~~**.**

[~~On the~~]**[0008]** **Building on a** basis of the article described above [~~"A~~]**"A** novel data format free bit-by-bit quasi-error monitoring method for optical transport [~~network"~~] **network"**, the main object is achieved [~~according to the methods specified in the independent patent claims 1, 2 and 3.~~] **by an embodiment of a method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values; additionally sampling the optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case the second threshold value is varied, producing second sampling values; comparing respective the first sampling values with the second sampling values, producing comparison values; integrating or summating the comparison values to produce, for each measuring interval, a summated comparison value; storing the summated comparison values; determining a distribution function of the comparison values as a function of the second variable threshold value after an adequate number of the measuring intervals; and improving the signal quality or optimizing the optical transmission system utilizing the distribution function.**

[~~An application of the methods~~]**[0009]** **In a further embodiment, the inventive object is achieved by a method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values; additionally sampling the optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case the second threshold value is varied, producing second sampling values; determining, for each the measuring interval, a first summated value in the measuring channel by integrating sampled logical zeros or ones; storing the first summated values; determining, for each measuring interval, a number of bits received as a summated bit value; storing the summated bit values; determining a probability function, after an adequate number of the measuring intervals, as a function of the**

variable second threshold value for an occurrence of a binary state from the stored first summated values and associated the summated bit values; and improving the signal quality or optimizing the optical transmission system utilizing the distribution function.

[0010] In a further embodiment, the inventive object is achieved by a method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values; additionally sampling the optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case the second threshold value is varied, producing second sampling values; determining, for each the measuring interval, a first summated value in the measuring channel by integrating sampled logical zeros or ones; storing the first summated values; determining, for each measuring interval, a second summated value in the working channel by integrating received zeros or ones; storing the second summated values; determining a probability function, after an adequate number of the measuring intervals, as a function of the variable second threshold value for an occurrence of a binary state from the stored first summated values and associated the second summated values; and improving the signal quality or optimizing the optical transmission system utilizing the distribution function.

[0011] The above methods can be applied by a method that further comprises the steps of measuring probability distributions with differently set dispersion values; storing measurement results; and obtaining, from the stored measurement results, an at least approximately optimum value for dispersion compensation ~~[is specified in claim 11 and an]~~**.**

[0012] These methods may be utilized in an inventive arrangement for measuring the signal quality ~~[is specified in the independent claim 13.~~

~~]~~**of WDM signals, comprising a channel selection circuit, with which a WDM channel is in each case selected; an optoelectronic conversion device that converts an optical signal; and a measuring device that is fed a signal after**

conversion by the optoelectronic conversion device that utilizes a probability distribution and determines a signal-to-noise ration as a main signal parameter.

[0013] It is advantageous in the case of the **first described** method [~~according to claim 1~~] that, by varying the threshold of a second decision circuit from measuring interval to measuring interval and by comparison of the sampled data, a probability distribution is measured and can be used to determine the distribution density function for the occurrence of specific receiving levels at the sampling instants - the sampled values. It is advantageous for the sampling to be followed by an integration of the binary decisions, so that only simple and slow processing is required.

[0014] A particularly advantageous design of the invention dispenses with the comparison of the bits sampled with different thresholds and counts [~~(integrates)~~]**(integrations)** within each measuring interval the bits assessed in the case of a specific threshold as logical ones (or as logical zeros) and also the number of bits. In the case of unbalanced codings, the number of logical ones (or logical zeros) in the working channel can also be assessed[~~,~~] in order to avoid fluctuations when there are different distributions of the binary states. The probability function is again determined from a large number of measurements with different sampling thresholds.

[0015] The use of a plurality of measuring channels with different sampling thresholds allows the measuring time to be reduced considerably.

[0016] On the basis of the distribution curves measured, the quality of the received binary signal, and consequently the properties of the optical transmission system, can be concluded. The knowledge gained can be used for optimizing the system, for example**,** the sampling and the dispersion compensation.

[0017] A suitable measuring device can carry out, in time-division multiplex mode, both the main signal parameters such as wavelength, power, signal-to-noise ratio and also statistical measurements.

DESCRIPTION OF THE DRAWINGS

[0018] The invention is explained in more detail on the basis of exemplary embodiments **and drawings described below.**

Figure 1 **is a schematic block diagram showing**[~~.~~
~~In the drawing:~~
~~figure 1 shows~~] a measuring device for measuring [~~the~~] **a** probability distribution[~~,~~]**;**

[~~figure 2 shows~~] **Figure 2** **is a graph showing** a probability density distribution [~~in dependence~~] **based** on different threshold values[~~,~~]**;**

[~~figure 3 shows~~] **Figure 3** **is a graph showing** a probability distribution measured with a circuit according to [~~figure 1,~~] **Figure 1;**

[~~figure 4 shows~~] **Figure 4** **is a schematic block diagram showing** a further measuring device for [
]measuring the probability distribution[~~,~~]**;**

[~~figure 5 shows~~] **Figure 5** **is a graph showing** an ideal probability density distribution[~~,~~]**;**

[~~figure 6 shows~~] **Figure 6** **is a graph showing** a measured probability distribution for different threshold values[~~,~~]**;**

[~~figure 7 shows~~] **Figure 7** **is a graph showing** a probability density derived from this **measured probability distribution;**

Figure 8 **is a graph showing**[~~,~~
~~figure 8 shows~~] a probability distribution of the binary states[~~,~~]**;**

[~~figure 9 shows~~] **Figure 9** **is a graph showing** the associated distribution density[~~,~~]**;**

[~~figure 10 shows~~] **Figure 10** **is a schematic block diagram showing** a variant of the further measuring device for faster measurement[~~,~~]**;**

[~~figure 11 shows~~] **Figure 11** **is a graph showing** probability density distributions [~~in dependence~~] **based** on the dispersion[~~,~~]**;**

[~~figure 12 shows~~] **Figure 12** **is a graph showing** the determination of the optimum dispersion compensation [~~and~~]**; and**

[~~figure 13 shows~~] **Figure 13** **is a schematic block diagram showing** a measuring arrangement.

DETAILED DESCRIPTION OF THE INVENTION

[0019] A measuring device for assessing the signal quality is represented in [~~figure~~] **Figure** 1. It includes a first sampling stage 1 in the [~~"working channel",~~]**"working channel",** which **(**at the instant of the effective edge of the clock signal C1**)** samples the electrical binary signal BS present in the base band with a first, at least approximately optimum, threshold value Sw (w - working channel). The adjustable threshold value Sw expediently lies approximately midway between the two ideal signal levels, which represent [~~the~~] **a** logical one and [~~the~~] **a** logical zero. In parallel with this, the sampling by [~~means~~] **way** of a second measuring sampling stage 2 takes place at the same time in a [~~"measuring channel"~~]**"measuring channel"**, the threshold value Sv (v - variable) [~~of which is~~] **being** likewise variable. The outputs of the two sampling stages are combined via an exclusive-OR gate 3, which gives as an output signal a comparison value, which **is a logical 1** in the case of unequal sampling [~~results is logical 1~~]. Within a measuring interval, the comparison values VD are summated by a (digital or analog) integrator 4. The summated comparison value [~~IW~~] **Iw** determined in this way is then written to a memory 5 of an evaluation unit (not represented) with an interval clock signal TI, which also re-sets the counters.

[0020] This operation is repeated for, [~~for example~~] **e.g.**, 200 different threshold values, until a distribution function that is as accurate as possible is obtained between the smallest and largest possible sampled value or threshold value.

[0021] For better understanding, [~~firstly~~] the distribution density of sampled values of a received binary signal is represented in [~~figure~~] **Figure** 2. This would be obtained - by contrast with the measurement with the device according to [~~figure~~] **Figure** 1 - if the amplitudes of the sampled values were measured directly. The horizontal axis gives the possible amplitudes of the sampled values Si; the distribution density P(Si) for the occurrence of sampled values with specific amplitudes S is represented on the vertical axis.

[0022] For the distribution density, $P(S) = \frac{\sum Si}{\sum Bits}$.

[0023] In the case of a depicted amplitude value S50, a first maximum occurs. This amplitude value corresponds approximately to the mean value for the logical zero. With increasing amplitude values, the distribution function decreases again, until it reaches a new maximum in the case of an amplitude value S150, which represents the average amplitude value for the logical one. The function subsequently falls again.

[0024] In the case of the measurement carried out with a measuring arrangement according to ~~[figure]~~ **Figure** 1, however, ~~[as already described,]~~ the individual amplitude values are no longer sampled and stored, since this would require very fast circuits. By contrast, ~~[it is assessed]~~ **an assessment is made as to** whether or not the sampled values in the two sampling stages coincide. Since, according to ~~[figure]~~ **Figure** 1, the unequal sampled values are integrated, a minimum is obtained in the case of the distribution function V(S) determined in ~~[figure]~~ **Figure** 3 when the sampling threshold values Sw and Sv are identical. If the variable threshold value Sv is now reduced, deviations will occur ever more frequently as the difference between the threshold values increases. A very low variable threshold value Sv of the second decision-circuit stage 2 will therefore almost always bring about ~~[an]~~ **a threshold** overshoot ~~[of the threshold]~~. Consequently, logical ones will predominate as sampled values in the measuring channel, although a logical zero was received as the bit~~[,]~~ **(**its level**,** however**,** being above the threshold**)**. With threshold values lying above the held-constant threshold value Sw and continuing to increase, an increase of the distribution function is likewise obtained, since from ~~[now]~~ **this point** on the sampling stage of the measuring channel emits the logical zero more frequently, since the required level is not reached by a logical one of the binary signal.

[0025] Since, in the case of the measuring device according to ~~[figure]~~ **Figure** 1, all **of** the sampled values lying above (or below) the variable threshold value Sv1 are assessed, the measured distribution function, ~~[figure]~~ **Figure** 3, corresponds to the integral of the distribution density function according to ~~[figure]~~ **Figure** 2. Or, to put it another way, ~~[figure]~~ **Figure** 2 is the absolute value of the derivative of the function represented in ~~[figure]~~ **Figure** 3. An integration value IW1 for two specific threshold values Sw and Sv1 is depicted as an example.

~~[Only if the variable threshold is changed in very fine stages is a]~~**[0026]** **A** relatively exact, and therefore smooth, distribution curve **is** obtained **only if the variable threshold is changed in very fine stages**. However, this is also only the case whenever the measurements are adequately exact and are not subject to statistical fluctuations. The measuring intervals for the different sampling threshold values should therefore be chosen to correspond to the different summated comparison values. When only a few differences occur, the measuring intervals are increased, whereas when frequent differences occur the measuring intervals can be reduced.

[0027] The evaluation of the distribution density curves can take place in a way corresponding to ~~[the]~~ **a** known method. It is generally customary to calculate a signal quality parameter Q:

[0028]

$$Q = \frac{A}{\sigma_a + \sigma_b}$$

[0029] where A = b - a is the signal amplitude and σa and σb are the standard deviations in the case of an assumed Gaussian distribution.

[0030] More details can ~~[be taken from the earlier application]~~ **found in German patent document** DE 19 812 078.8 or C. Glingener: ~~["Modellierung]~~**"Modellierung** und Simulation faseroptischer Netze mit Wellenlä~~[ngenmultiplex" (modelling and simulation of fiber-optic networks with wavelength division multiplexing]~~ **ngenmultiplex" (Modelling and Simulation of Fiber-optic Networks with Wavelength Division Multiplexing**]; WFT-Verlag, 1998, pages 102 to 118**, both incorporated herein by reference.**

[0031]~~[-~~

~~]~~ A further particularly advantageous device for measuring a probability distribution, from which the distribution density can likewise be derived, is represented in ~~[figure]~~ **Figure** 4. This circuit again contains two sampling stages 1 and 2, but up to three counters or integrators 6, 7 and 8. The first counter 6 counts the number IB of bits during a measuring interval, the summated bit value. The second counter 7 is connected in the working channel to the output is of the sampling stage 1 and counts the number of logical ones,

referred to as the second summated value IE, during a measuring interval. The third counter 8 is connected in the measuring channel to the output of the second sampling stage 2 and likewise counts the number IV of bits VE assessed with logical one in the case of different threshold values Sv, the first summated value IV. The summated values IB, IE and IV are fed at the end of a measuring interval to an intermediate processing device 9, in which the normalization takes place, or are initially written to the memory and are later normalized and processed. After that, the measuring operation is repeated with a changed sampling threshold, until the probability distribution WV(S) represented in [~~figure~~] **Figure** 6 can be determined.

[~~If~~]**[0032]** **If one initially assumes** an equal distribution of logical ones and zeros of the binary signal BS [~~is initially assumed~~], the probability density WD(S) represented in [~~figure~~] **Figure** 5 would be obtained [~~in an evaluation of~~] **when evaluating** the sampled values.

[~~With the~~]**[0033]** **The** measuring device according to [~~figure~~] **Figure** 4, however, **measures** the probability of the occurrence of a specific binary state [~~is measured~~]. If**,** at the beginning**,** such a low threshold value is used that all **of** the received signal values in the measuring channel lie above the threshold and are therefore assessed as logical ones, a greatest possible probability is determined. If the threshold value is then increased from measuring interval to measuring interval, the probability will initially be reduced steadily until, in the case of an average threshold value - assuming an equal distribution of logical zeros and ones - it lies around 0.5, to then decrease again to zero. The determination of the number of bits during a measuring interval serves for normalizing the measurement results in the case of measuring intervals of unequal length. For the probability distribution of logical zeros in the measuring channel, a complementary distribution function depicted by dashed lines would be obtained.

[0034] In a way corresponding to the relationships already indicated in the case of the measuring arrangement according to [~~figure~~] **Figure** 1, it is possible**,** by differentiating the distribution function according to [~~figure~~] **Figure** 6 and forming an absolute value**,** to determine the probability density WDI according to [~~figure~~] **Figure** 7, which is [~~"inverse"~~]**"inverse"** to the distribution density of the

sampled values of the signal (or the probability density function of the logical zeros is determined, or this problem is avoided by absolute value formation).

[0035] In the case of the measuring arrangement, it is immaterial whether the occurrence of logical ones or logical zeros is assessed. As an alternative to the counting of the bits within a measuring interval, both sampled values zero and one can also be counted, since they go together to make up the total number of bits received. If there is an equal distribution of logical ones and zeros, it is also possible to dispense with the counter 7 summating the logical ones. On the other hand, the counter is required[~~,~~] in order to eliminate the influence of an unequal distribution of zeros and ones to the greatest extent by forming the quotient of the summated values in the measuring channel and in the working channel.

[0036] In a way corresponding to [~~figure~~] **Figure** 8, the difference between the summated values IE - IV can also be evaluated for a binary state, here [~~the~~] **a** logical one, for [

]the first sampling stage 1 and the measuring sampling stage 2. This measure has approximately the same effect as that of the circuit indicated in [~~figure~~] **Figure** 1: the differences between the working channel and the measuring channel are assessed. The difference formation can be combined with the quotient formation. In comparison with [~~figure~~] **Figure** 6, there is a horizontal shift of the probability distribution function WW. The probability function can again be used to determine the probability density distribution represented in [~~figure~~] **Figure** 9, which is particularly suitable for the evaluation. Since, however, the two functions can be mathematically transformed into each other, in principle the evaluation of the distribution function is also always possible.

[0037] A measuring device allowing a reduction in the measuring time required overall for creating a probability distribution is represented in [~~figure~~] **Figure** 10. If only one sampling stage with a variable threshold is provided, this threshold must be changed after each measuring interval for a new measurement. If, on the other hand, a plurality of sampling stages 21 to 2n with different threshold values Sv1 - Svn are used, a plurality of measurements can be carried out simultaneously and the total measuring time can be

correspondingly reduced. Only **a** little additional hardware expenditure is required for the sampling ~~[flipflops]~~ **flip-flops** and integrators 81 to 8n. The same also applies correspondingly to the measuring arrangement according to ~~[figure 1. For reasons of costs, it]~~ **Figure 1. It** is not yet economical to create an arrangement with the same number of sampling stages as the number of necessary threshold ~~[values. If that were the case]~~ **values—however, in such an arrangement**, only one measuring interval would be required.

[0038] For further measuring purposes, ~~[[lacuna]]~~ **an embodiment of the arrangement may** change the sampling instant of the measuring/sampling stage ~~[by means of]~~ **using** a phase shifter 16 ~~[(figure]~~**(Figure** 4), to which a clock signal ~~[LV]~~ **CLV** leading the regular clock signal ~~[C1]~~ **CL** is fed. If this measure is additionally carried out, the entire eye pattern can be acquired on the basis of statistical measurements.

[0039] The dependence of the distribution density function in the case of different dispersion values is represented in ~~[figure]~~ **Figure** 11. If there is a change in dispersion, the spacing of the maxima of the distribution density function changes. When a transmission system is being installed or optimized, the dispersion is increased or reduced - starting from a value of zero - with the aid of an adjustable dispersion compensator/emulator 15 connected into the signal path. The measurement of the probability distribution and the determination of the spacing ΔS between the maxima of the values for zero and one subsequently takes place in each case. If there are relatively great deviations of the dispersion from the optimum, there is a reduction in the spacings of the maxima for the occurrence of the sampled values assigned to the two binary signal values, both in the case of negative deviations and in the case positive deviations of the dispersion. In dependence on the change in dispersion, given in ps/nm (picoseconds/nanometer), the spacings between the maxima of the distribution density function are given on the y-axis in ~~[figure]~~ **Figure** 12. The optimization is carried out by ~~[evaluation of]~~ **evaluating** the spacing function ΔS. For example, in a way corresponding to ~~[figure]~~ **Figure** 12, the falling edges of the measuring curve are extended; their point of intersection determines the optimum dispersion. The measuring curves are again obtained with an arrangement according to ~~[figure]~~ **Figures** 1, 4 or 10.

~~[Alternatively,... can... [lacuna]~~

~~]~~**[0040]** The measuring arrangement for wavelength-division multiplex signals (WDM signals) is represented in ~~[figure]~~ **Figure** 13. Part of the binary signal is branched off by an optical coupler 9 and fed via a ~~[tunable]~~ **tuneable** filter 10 and an optoelectronic transducer 12 to a measuring and evaluation unit 13 as an electrical baseband signal. This unit measures the most important channel parameters~~[,]~~ **(**such as channel power, wavelength, signal-to-noise ratio**)**, but also carries out statistical measurements of the signal quality, as described above, in order ~~[for example]~~**, e.g.,** to be able to make statements concerning the bit error rate, which are transferred to a management system TMN.

[0041] The main part of the measuring device is an optical spectrum analyzer, with which main properties such as the level, wavelength and signal-to-noise ratio can be determined. The ~~[tunable]~~ **tuneable** filter acts as a multiplexing device~~[,]~~ to allow the measurements to be carried out with reasonable expenditure. The wavelength of the tuned filter can be set with adequate accuracy with the aid of a calibrating device 11.

[0042] A controller 14 undertakes the successive testing of the individual WDM channels with the aid of a channel selection circuit 17~~[. It]~~ **which** determines the type of measurement. In the case of statistical measurements, it also determines the duration of the measuring intervals.

[0043] The above-described method and apparatus are illustrative of the principles of the present invention. Numerous modifications and adaptations will be readily apparent to those skilled in this art without departing from the spirit and scope of the present invention.

ABSTRACT

~~[Method and arrangement for measuring the signal quality in optical networks~~

]A received binary signal (BS) is sampled with different thresholds, the sampling results are integrated and stored. The measured probability distributions or probability density distributions can be used to draw conclusions concerning the signal quality~~[,]~~ (for example, the bit error rate~~[,]~~) and to optimize the system.

~~[Figure 4]~~

SPECIFICATION

TITLE

METHOD AND ARRANGEMENT FOR MEASURING DISTRIBUTION FUNCTIONS FOR DETERMINING THE SIGNAL QUALITY IN OPTICAL TRANSMISSION SYSTEMS

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The invention relates to methods for measuring distribution functions for determining the signal quality in an optical transmission systems. A suitable arrangement makes it possible to measure the statistical properties and main signal parameters. The measurement results can be used for improving the signal quality, for example, for optimizing the dispersion compensation.

[0002] Statements concerning the quality of a received binary signal, and consequently also the properties of the transmission system and the transmission link, can be made based on statistical evaluations and measurements of distribution functions. These statements can in turn be used for optimizing the system, for example, for setting an optimum sampling instant, for setting an optimum sampling threshold, or for dispersion compensation.

DESCRIPTION OF THE RELATED ART

[0003] German patent document DE 195 04 896 A1 discloses signal quality monitoring of transparent optical networks in which a random signal sampling is performed. The random amplitude samples obtained in this way are evaluated using a known statistical method. German patent document DE 198 17 078.8 further develops this method by evaluating only the outer edges of a probability density function derived from the measurement results. This allows, for example, the bit error rate to be estimated. However, this method requires very fast sampling and storing capabilities.

[0004] United States patent number 5,585,954 describes an arrangement for measuring the error rate in the case of different decision-circuit threshold values based on a predetermined pseudo-random sequence, used for determining the transmission characteristic. However, the data transmission has

to be interrupted for this purpose. The measured bit error rate is only conditionally suitable for establishing non-linear effects.

[0005] In a paper by Hitoshi Takashita and Naoya Henmi Optical Fiber Communication Conference (OFC) 99, San Diego, California, FJ 2-1, pp. 149 - 151, an article titled “A novel data format free bit-by-bit quasi-error monitoring method for optical transport network” describes the use of a receiving circuit with two sampling circuits which have different thresholds. By sampling the binary signal with two different thresholds, a quasi bit error rate is measured and a direct correlation with the bit error rate is established. No further statistical statements are made.

SUMMARY OF THE INVENTION

[0006] The object of the invention is to provide measuring methods for determining distribution functions which can be statistically evaluated.

[0007] Further inventive objects include providing an application for improving the signal quality, for example, by optimizing the dispersion compensation, and a suitable measuring arrangement.

[0008] Building on a basis of the article described above “A novel data format free bit-by-bit quasi-error monitoring method for optical transport network”, the main object is achieved by an embodiment of a method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values; additionally sampling the optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case the second threshold value is varied, producing second sampling values; comparing respective the first sampling values with the second sampling values, producing comparison values; integrating or summating the comparison values to produce, for each measuring interval, a summated comparison value; storing the summated comparison values; determining a distribution function of the comparison values as a function of the second variable threshold value after an adequate number of the measuring intervals; and improving the signal quality or optimizing the optical transmission system utilizing the distribution function.

[0009] In a further embodiment, the inventive object is achieved by a method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values; additionally sampling the optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case the second threshold value is varied, producing second sampling values; determining, for each the measuring interval, a first summated value in the measuring channel by integrating sampled logical zeros or ones; storing the first summated values; determining, for each measuring interval, a number of bits received as a summated bit value; storing the summated bit values; determining a probability function, after an adequate number of the measuring intervals, as a function of the variable second threshold value for an occurrence of a binary state from the stored first summated values and associated the summated bit values; and improving the signal quality or optimizing the optical transmission system utilizing the distribution function.

[0010] In a further embodiment, the inventive object is achieved by a method of measuring a distribution function for determining a signal quality in optical transmission systems, comprising the steps of sampling an optical binary signal in a working channel with a first threshold value, producing first sampling values; additionally sampling the optical binary signal in a measuring channel with a second threshold value during a plurality of measuring intervals in which in each case the second threshold value is varied, producing second sampling values; determining, for each the measuring interval, a first summated value in the measuring channel by integrating sampled logical zeros or ones; storing the first summated values; determining, for each measuring interval, a second summated value in the working channel by integrating received zeros or ones; storing the second summated values; determining a probability function, after an adequate number of the measuring intervals, as a function of the variable second threshold value for an occurrence of a binary state from the stored first summated values and associated the second summated values; and improving the signal quality or optimizing the optical transmission system utilizing the distribution function.

[0011] The above methods can be applied by a method that further comprises the steps of measuring probability distributions with differently set dispersion values; storing measurement results; and obtaining, from the stored measurement results, an at least approximately optimum value for dispersion compensation.

[0012] These methods may be utilized in an inventive arrangement for measuring the signal quality of WDM signals, comprising a channel selection circuit, with which a WDM channel is in each case selected; an optoelectronic conversion device that converts an optical signal; and a measuring device that is fed a signal after conversion by the optoelectronic conversion device that utilizes a probability distribution and determines a signal-to-noise ration as a main signal parameter.

[0013] It is advantageous in the case of the first described method that, by varying the threshold of a second decision circuit from measuring interval to measuring interval and by comparison of the sampled data, a probability distribution is measured and can be used to determine the distribution density function for the occurrence of specific receiving levels at the sampling instants - the sampled values. It is advantageous for the sampling to be followed by an integration of the binary decisions, so that only simple and slow processing is required.

[0014] A particularly advantageous design of the invention dispenses with the comparison of the bits sampled with different thresholds and counts (integrations) within each measuring interval the bits assessed in the case of a specific threshold as logical ones (or as logical zeros) and also the number of bits. In the case of unbalanced codings, the number of logical ones (or logical zeros) in the working channel can also be assessed in order to avoid fluctuations when there are different distributions of the binary states. The probability function is again determined from a large number of measurements with different sampling thresholds.

[0015] The use of a plurality of measuring channels with different sampling thresholds allows the measuring time to be reduced considerably.

[0016] On the basis of the distribution curves measured, the quality of the received binary signal, and consequently the properties of the optical transmission system, can be concluded. The knowledge gained can be used for optimizing the system, for example, the sampling and the dispersion compensation.

[0017] A suitable measuring device can carry out, in time-division multiplex mode, both the main signal parameters such as wavelength, power, signal-to-noise ratio and also statistical measurements.

DESCRIPTION OF THE DRAWINGS

[0018] The invention is explained in more detail on the basis of exemplary embodiments and drawings described below.

Figure 1 is a schematic block diagram showing a measuring device for measuring a probability distribution;

Figure 2 is a graph showing a probability density distribution based on different threshold values;

Figure 3 is a graph showing a probability distribution measured with a circuit according to Figure 1;

Figure 4 is a schematic block diagram showing a further measuring device for measuring the probability distribution;

Figure 5 is a graph showing an ideal probability density distribution;

Figure 6 is a graph showing a measured probability distribution for different threshold values;

Figure 7 is a graph showing a probability density derived from this measured probability distribution;

Figure 8 is a graph showing a probability distribution of the binary states;

Figure 9 is a graph showing the associated distribution density;

Figure 10 is a schematic block diagram showing a variant of the further measuring device for faster measurement;

Figure 11 is a graph showing probability density distributions based on the dispersion;

Figure 12 is a graph showing the determination of the optimum dispersion compensation; and

Figure 13 is a schematic block diagram showing a measuring arrangement.

DETAILED DESCRIPTION OF THE INVENTION

[0019] A measuring device for assessing the signal quality is represented in Figure 1. It includes a first sampling stage 1 in the "working channel", which (at the instant of the effective edge of the clock signal C1) samples the electrical binary signal BS present in the base band with a first, at least approximately optimum, threshold value Sw (w - working channel). The adjustable threshold value Sw expediently lies approximately midway between the two ideal signal levels, which represent a logical one and a logical zero. In parallel with this, the sampling by way of a second measuring sampling stage 2 takes place at the same time in a "measuring channel", the threshold value Sv (v - variable) being likewise variable. The outputs of the two sampling stages are combined via an exclusive-OR gate 3, which gives as an output signal a comparison value, which is a logical 1 in the case of unequal sampling. Within a measuring interval, the comparison values VD are summated by a (digital or analog) integrator 4. The summated comparison value Iw determined in this way is then written to a memory 5 of an evaluation unit (not represented) with an interval clock signal TI, which also re-sets the counters.

[0020] This operation is repeated for, e.g., 200 different threshold values, until a distribution function that is as accurate as possible is obtained between the smallest and largest possible sampled value or threshold value.

[0021] For better understanding, the distribution density of sampled values of a received binary signal is represented in Figure 2. This would be obtained - by contrast with the measurement with the device according to Figure 1 - if the amplitudes of the sampled values were measured directly. The horizontal axis gives the possible amplitudes of the sampled values Si; the distribution density P(Si) for the occurrence of sampled values with specific amplitudes S is represented on the vertical axis.

[0022] For the distribution density, $P(S) = \frac{\sum Si}{\sum Bits}$.

[0023] In the case of a depicted amplitude value S50, a first maximum occurs. This amplitude value corresponds approximately to the mean value for

the logical zero. With increasing amplitude values, the distribution function decreases again, until it reaches a new maximum in the case of an amplitude value S150, which represents the average amplitude value for the logical one. The function subsequently falls again.

[0024] In the case of the measurement carried out with a measuring arrangement according to Figure 1, however, the individual amplitude values are no longer sampled and stored, since this would require very fast circuits. By contrast, an assessment is made as to whether or not the sampled values in the two sampling stages coincide. Since, according to Figure 1, the unequal sampled values are integrated, a minimum is obtained in the case of the distribution function V(S) determined in Figure 3 when the sampling threshold values Sw and Sv are identical. If the variable threshold value Sv is now reduced, deviations will occur ever more frequently as the difference between the threshold values increases. A very low variable threshold value Sv of the second decision-circuit stage 2 will therefore almost always bring about a threshold overshoot. Consequently, logical ones will predominate as sampled values in the measuring channel, although a logical zero was received as the bit (its level, however, being above the threshold). With threshold values lying above the held-constant threshold value Sw and continuing to increase, an increase of the distribution function is likewise obtained, since from this point on the sampling stage of the measuring channel emits the logical zero more frequently, since the required level is not reached by a logical one of the binary signal.

[0025] Since, in the case of the measuring device according to Figure 1, all of the sampled values lying above (or below) the variable threshold value Sv1 are assessed, the measured distribution function, Figure 3, corresponds to the integral of the distribution density function according to Figure 2. Or, to put it another way, Figure 2 is the absolute value of the derivative of the function represented in Figure 3. An integration value IW1 for two specific threshold values Sw and Sv1 is depicted as an example.

[0026] A relatively exact, and therefore smooth, distribution curve is obtained only if the variable threshold is changed in very fine stages. However, this is also only the case whenever the measurements are adequately exact and are not subject to statistical fluctuations. The measuring intervals for the

different sampling threshold values should therefore be chosen to correspond to the different summated comparison values. When only a few differences occur, the measuring intervals are increased, whereas when frequent differences occur the measuring intervals can be reduced.

[0027] The evaluation of the distribution density curves can take place in a way corresponding to a known method. It is generally customary to calculate a signal quality parameter Q:

[0028]
$$Q = \frac{A}{\sigma_a + \sigma_b}$$

[0029] where A = b - a is the signal amplitude and σa and σb are the standard deviations in the case of an assumed Gaussian distribution.

[0030] More details can found in German patent document DE 19 812 078.8 or C. Glingener: "Modellierung und Simulation faseroptischer Netze mit Wellenlängenmultiplex" (Modelling and Simulation of Fiber-optic Networks with Wavelength Division Multiplexing]; WFT-Verlag, 1998, pages 102 to 118, both incorporated herein by reference.

[0031] A further particularly advantageous device for measuring a probability distribution, from which the distribution density can likewise be derived, is represented in Figure 4. This circuit again contains two sampling stages 1 and 2, but up to three counters or integrators 6, 7 and 8. The first counter 6 counts the number IB of bits during a measuring interval, the summated bit value. The second counter 7 is connected in the working channel to the output is of the sampling stage 1 and counts the number of logical ones, referred to as the second summated value IE, during a measuring interval. The third counter 8 is connected in the measuring channel to the output of the second sampling stage 2 and likewise counts the number IV of bits VE assessed with logical one in the case of different threshold values Sv, the first summated value IV. The summated values IB, IE and IV are fed at the end of a measuring interval to an intermediate processing device 9, in which the normalization takes place, or are initially written to the memory and are later normalized and processed. After that, the measuring operation is repeated with a changed

sampling threshold, until the probability distribution WV(S) represented in Figure 6 can be determined.

[0032] If one initially assumes an equal distribution of logical ones and zeros of the binary signal BS, the probability density WD(S) represented in Figure 5 would be obtained when evaluating the sampled values.

[0033] The measuring device according to Figure 4, however, measures the probability of the occurrence of a specific binary state. If, at the beginning, such a low threshold value is used that all of the received signal values in the measuring channel lie above the threshold and are therefore assessed as logical ones, a greatest possible probability is determined. If the threshold value is then increased from measuring interval to measuring interval, the probability will initially be reduced steadily until, in the case of an average threshold value - assuming an equal distribution of logical zeros and ones - it lies around 0.5, to then decrease again to zero. The determination of the number of bits during a measuring interval serves for normalizing the measurement results in the case of measuring intervals of unequal length. For the probability distribution of logical zeros in the measuring channel, a complementary distribution function depicted by dashed lines would be obtained.

[0034] In a way corresponding to the relationships already indicated in the case of the measuring arrangement according to Figure 1, it is possible, by differentiating the distribution function according to Figure 6 and forming an absolute value, to determine the probability density WDI according to Figure 7, which is "inverse" to the distribution density of the sampled values of the signal (or the probability density function of the logical zeros is determined, or this problem is avoided by absolute value formation).

[0035] In the case of the measuring arrangement, it is immaterial whether the occurrence of logical ones or logical zeros is assessed. As an alternative to the counting of the bits within a measuring interval, both sampled values zero and one can also be counted, since they go together to make up the total number of bits received. If there is an equal distribution of logical ones and zeros, it is also possible to dispense with the counter 7 summating the logical ones. On the other hand, the counter is required in order to eliminate the

influence of an unequal distribution of zeros and ones to the greatest extent by forming the quotient of the summated values in the measuring channel and in the working channel.

[0036] In a way corresponding to Figure 8, the difference between the summated values IE - IV can also be evaluated for a binary state, here a logical one, for the first sampling stage 1 and the measuring sampling stage 2. This measure has approximately the same effect as that of the circuit indicated in Figure 1: the differences between the working channel and the measuring channel are assessed. The difference formation can be combined with the quotient formation. In comparison with Figure 6, there is a horizontal shift of the probability distribution function WW. The probability function can again be used to determine the probability density distribution represented in Figure 9, which is particularly suitable for the evaluation. Since, however, the two functions can be mathematically transformed into each other, in principle the evaluation of the distribution function is also always possible.

[0037] A measuring device allowing a reduction in the measuring time required overall for creating a probability distribution is represented in Figure 10. If only one sampling stage with a variable threshold is provided, this threshold must be changed after each measuring interval for a new measurement. If, on the other hand, a plurality of sampling stages 21 to 2n with different threshold values Sv1 - Svn are used, a plurality of measurements can be carried out simultaneously and the total measuring time can be correspondingly reduced. Only a little additional hardware expenditure is required for the sampling flip-flops and integrators 81 to 8n. The same also applies correspondingly to the measuring arrangement according to Figure 1. It is not yet economical to create an arrangement with the same number of sampling stages as the number of necessary threshold values—however, in such an arrangement, only one measuring interval would be required.

[0038] For further measuring purposes, an embodiment of the arrangement may change the sampling instant of the measuring/sampling stage using a phase shifter 16 (Figure 4), to which a clock signal CLV leading the regular clock signal CL is fed. If this measure is additionally carried out, the entire eye pattern can be acquired on the basis of statistical measurements.

[0039] The dependence of the distribution density function in the case of different dispersion values is represented in Figure 11. If there is a change in dispersion, the spacing of the maxima of the distribution density function changes. When a transmission system is being installed or optimized, the dispersion is increased or reduced - starting from a value of zero - with the aid of an adjustable dispersion compensator/emulator 15 connected into the signal path. The measurement of the probability distribution and the determination of the spacing ΔS between the maxima of the values for zero and one subsequently takes place in each case. If there are relatively great deviations of the dispersion from the optimum, there is a reduction in the spacings of the maxima for the occurrence of the sampled values assigned to the two binary signal values, both in the case of negative deviations and in the case positive deviations of the dispersion. In dependence on the change in dispersion, given in ps/nm (picoseconds/nanometer), the spacings between the maxima of the distribution density function are given on the y-axis in Figure 12. The optimization is carried out by evaluating the spacing function ΔS. For example, in a way corresponding to Figure 12, the falling edges of the measuring curve are extended; their point of intersection determines the optimum dispersion. The measuring curves are again obtained with an arrangement according to Figures 1, 4 or 10.

[0040] The measuring arrangement for wavelength-division multiplex signals (WDM signals) is represented in Figure 13. Part of the binary signal is branched off by an optical coupler 9 and fed via a tuneable filter 10 and an optoelectronic transducer 12 to a measuring and evaluation unit 13 as an electrical baseband signal. This unit measures the most important channel parameters (such as channel power, wavelength, signal-to-noise ratio), but also carries out statistical measurements of the signal quality, as described above, in order, e.g., to be able to make statements concerning the bit error rate, which are transferred to a management system TMN.

[0041] The main part of the measuring device is an optical spectrum analyzer, with which main properties such as the level, wavelength and signal-to-noise ratio can be determined. The tuneable filter acts as a multiplexing device to allow the measurements to be carried out with reasonable expenditure. The

wavelength of the tuned filter can be set with adequate accuracy with the aid of a calibrating device 11.

[0042] A controller 14 undertakes the successive testing of the individual WDM channels with the aid of a channel selection circuit 17 which determines the type of measurement. In the case of statistical measurements, it also determines the duration of the measuring intervals.

[0043] The above-described method and apparatus are illustrative of the principles of the present invention. Numerous modifications and adaptations will be readily apparent to those skilled in this art without departing from the spirit and scope of the present invention.

ABSTRACT

A received binary signal (BS) is sampled with different thresholds, the sampling results are integrated and stored. The measured probability distributions or probability density distributions can be used to draw conclusions concerning the signal quality (for example, the bit error rate) and to optimize the system.

GR 99 P 1578 8/prts

Description

Method and arrangement for measuring the signal quality in an optical transmission system

The invention relates to a method and an arrangement for measuring the signal quality in an optical transmission system. The results can be used for improving the signal quality, for example for optimizing the dispersion compensation.

On the basis of the measurements of statistical properties of a received binary signal, statements can be made concerning its quality, and consequently also the properties of the transmission system and the transmission link. These statements can in turn be used for optimizing the system, for example for setting an optimum sampling instant, an optimum sampling threshold or for dispersion compensation.

German Offenlegungsschrift DE 195 04 896 A1 discloses a monitoring of the signal quality of transparent optical networks in which a random sampling of a signal is performed. The random amplitude samples obtained in this way are evaluated by means of a known statistical method. In an earlier patent application, application number ... DE 198 17 078. 8, this method is further developed in that only the outer edges of a probability density function derived from the measurement results are evaluated. This allows for example the bit error rate to be estimated. However, the method described here requires very fast sampling and storing capabilities.

In a paper by Hitoshi Takashita and Naoya Henmi Optical Fiber Communication Conference (OFC) 99, San Diego, California, FJ 2-1, pp. 149 - 151, in an article "A novel data format free bit-by-bit quasi-error monitoring method for

optical transport network" a receiving circuit with two sampling circuits which have different thresholds is used. Measurements are used to establish a direct correlation between the bit error rate and the comparison results of the two sampling circuits. No further statistical statements are made.

The object of the invention is to specify measuring methods by which distribution functions which can be statistically evaluated can be determined.

In further subobjects, the application for improving the signal quality, for example by optimizing the dispersion compensation, and a suitable measuring arrangement are to be specified.

The main object is achieved [lacuna] method specified in independent patent claims 1 and 2.

An application of the method for dispersion compensation is specified in claim 10 and an arrangement for measuring the signal quality is specified in the independent claim 12.

It is advantageous in the case of the method according to claim 1 that, by varying the threshold of a second decision circuit from measuring interval to measuring interval and by comparison of the sampled data, a probability distribution is measured and can be used to determine the distribution density function for the occurrence of specific receiving levels at the sampling instants - the sampled values. It is advantageous for the sampling to be followed by an integration of the binary decisions, so that only simple and slow processing is required.

A particularly advantageous design of the invention dispenses with the comparison of the bits sampled with

different thresholds and counts (integrates) within each

measuring interval the bits assessed in the case of a specific threshold as logical ones (or as logical zeros) and also the number of bits. In the case of unbalanced codings, the number of logical ones (or logical zeros) in the working channel can also be assessed, in order to avoid fluctuations when there are different distributions of the binary states. The probability function is again determined from a large number of measurements with different sampling thresholds.

The use of a plurality of measuring channels with different sampling thresholds allows the measuring time to be reduced considerably.

On the basis of the distribution curves measured, the quality of the received binary signal, and consequently the properties of the optical transmission system, can be concluded. The knowledge gained can be used for optimizing the system, for example the sampling and the dispersion compensation.

A suitable measuring device can carry out, in time-division multiplex mode, both the main signal parameters such as wavelength, power, signal-to-noise ratio and also statistical measurements.

The invention is explained in more detail on the basis of exemplary embodiments.

In the drawing:

figure 1 shows a measuring device for measuring the probability distribution,

figure 2 shows a probability density distribution in dependence on different threshold values,

figure 3 shows a probability distribution measured with a circuit according to figure 1,

figure 4 shows a further measuring device for measuring the probability distribution,

figure 5 shows an ideal probability density distribution,

figure 6 shows a measured probability distribution for different threshold values,

figure 7 shows a probability density derived from this,

figure 8 shows a probability distribution of the binary states,

figure 9 shows the associated distribution density,

figure 10 shows a variant of the further measuring device for faster measurement,

figure 11 shows probability density distributions in dependence on the dispersion,

figure 12 shows the determination of the optimum dispersion compensation and

figure 13 shows a measuring arrangement.

A measuring device for assessing the signal quality is represented in figure 1. It includes a first sampling stage 1 in the "working channel", which at the instant of the effective edge of the clock signal Cl samples the electrical binary signal BS present in the base band with a first, at least approximately optimum, threshold value Sw (w - working channel). The adjustable threshold value Sw expediently lies approximately midway between the two ideal signal levels, which represent the logical one and the logical zero. In parallel with this, the sampling by means of a second measuring sampling stage 2 takes place at the same time in a "measuring channel", the threshold value Sv (v - variable) of which is likewise variable. The outputs of the two sampling stages are combined via an exclusive-OR gate 3, which gives as an output signal a comparison value, which in the case of unequal sampling results is logical 1. Within a measuring interval, the comparison values VD are summated by a (digital or

analog) integrator 4. The summated comparison value IW determined in this way is then written to a memory 5 of an evaluation unit (not represented) with an interval clock signal TI, which also re-sets the counters.

This operation is repeated for, for example, 200 different threshold values, until a distribution function that is as accurate as possible is obtained between the smallest and largest possible sampled value or threshold value.

For better understanding, firstly the distribution density of sampled values of a received binary signal is represented in figure 2. This would be obtained - by contrast with the measurement with the device according to figure 1 - if the amplitudes of the sampled values were measured directly. The horizontal axis gives the possible amplitudes of the sampled values Si; the distribution density P(Si) for the occurrence of sampled values with specific amplitudes S is represented on the vertical axis.

For the distribution density, $P(S) = \frac{\sum Si}{\sum Bits}$.

In the case of a depicted amplitude value S_{50}, a first maximum occurs. This amplitude value corresponds approximately to the mean value for the logical zero. With increasing amplitude values, the distribution function decreases again, until it reaches a new maximum in the case of an amplitude value S_{150}, which represents the average amplitude value for the logical one. The function subsequently falls again.

In the case of the measurement carried out with a measuring arrangement according to figure 1, however, as already described, the individual amplitude values are no longer sampled and stored, since this would require very fast circuits. By contrast, it is assessed whether or not the sampled values in the two sampling stages coincide. Since, according to figure 1, the unequal sampled values are integrated, a minimum is obtained in the case of the distribution function

V(S) determined in figure 3 when the sampling threshold values Sw and Sv are identical. If the variable threshold value Sv is now reduced, deviations will occur ever more frequently as the difference between the threshold values increases. A very low variable threshold value Sv of the second decision-circuit stage 2 will therefore almost always bring about an

overshoot of the threshold. Consequently, logical ones will predominate as sampled values in the measuring channel, although a logical zero was received as the bit, its level however being above the threshold. With threshold values lying above the held-constant threshold value Sw and continuing to increase, an increase of the distribution function is likewise obtained, since from now on the sampling stage of the measuring channel emits the logical zero more frequently, since the required level is not reached by a logical one of the binary signal.

Since, in the case of the measuring device according to figure 1, all the sampled values lying above (or below) the variable threshold value Sv1 are assessed, the measured distribution function, figure 3, corresponds to the integral of the distribution density function according to figure 2. Or, to put it another way, figure 2 is the absolute value of the derivative of the function represented in figure 3. An integration value IW1 for two specific threshold values Sw and Sv1 is depicted as an example.

Only if the variable threshold is changed in very fine stages is a relatively exact, and therefore smooth, distribution curve obtained. However, this is also only the case whenever the measurements are adequately exact and are not subject to statistical fluctuations. The measuring intervals for the different sampling threshold values should therefore be chosen to correspond to the different summated comparison values. When only a few differences occur, the measuring intervals are increased, whereas when frequent differences occur the measuring intervals can be reduced.

The evaluation of the distribution density curves can take place in a way corresponding to the known method.

It is generally customary to calculate a signal quality parameter Q:

$$Q = \frac{A}{\sigma_a + \sigma_b}$$

where A = b - a is the signal amplitude and σ_a and σ_b are the standard deviations in the case of an assumed Gaussian distribution. More details can be taken from the earlier application DE 19 812 078.8 or C. Glingener: "Modellierung und Simulation faseroptischer Netze mit Wellenlängenmultiplex" (modelling and simulation of fiber-optic networks with wavelength division multiplexing]; WFT-Verlag, 1998, pages 102 to 118.

A further particularly advantageous device for measuring a probability distribution, from which the distribution density can likewise be derived, is represented in figure 4. This circuit again contains two sampling stages 1 and 2, but up to three counters or integrators 6, 7 and 8. The first counter 6 counts the number IB of bits during a measuring interval, the summated bit value. The second counter 7 is connected in the working channel to the output is of the sampling stage 1 and counts the number of logical ones, referred to as the second summated value IE, during a measuring interval. The third counter 8 is connected in the measuring channel to the output of the second sampling stage 2 and likewise counts the number IV of bits VE assessed with logical one in the case of different threshold values Sv, the first summated value IV. The summated values IB, IE and IV are fed at the end of a measuring interval to an intermediate processing device 9, in which the normalization takes place, or are initially written to the memory and are later normalized and processed. After that, the measuring operation is repeated with a changed sampling threshold, until the probability distribution WV(S) represented in figure 6 can be determined.

If an equal distribution of logical ones and zeros of the binary signal BS is initially assumed, the probability density WD(S) represented in figure 5 would

be obtained in an evaluation of the sampled values.

With the measuring device according to figure 4, however, the probability of the occurrence of a specific binary state is measured. If at the beginning such a low threshold value is used

that all the received signal values in the measuring channel lie above the threshold and are therefore assessed as logical ones, a greatest possible probability is determined. If the threshold value is then increased from measuring interval to measuring interval, the probability will initially be reduced steadily until, in the case of an average threshold value - assuming an equal distribution of logical zeros and ones - it lies around 0.5, to then decrease again to zero. The determination of the number of bits during a measuring interval serves for normalizing the measurement results in the case of measuring intervals of unequal length. For the probability distribution of logical zeros in the measuring channel, a complementary distribution function depicted by dashed lines would be obtained.

In a way corresponding to the relationships already indicated in the case of the measuring arrangement according to figure 1, it is possible by differentiating the distribution function according to figure 6 and forming an absolute value to determine the probability density WDI according to figure 7, which is "inverse" to the distribution density of the sampled values of the signal (or the probability density function of the logical zeros is determined or this problem is avoided by absolute value formation).

In the case of the measuring arrangement, it is immaterial whether the occurrence of logical ones or logical zeros is assessed. As an alternative to the counting of the bits within a measuring interval, both sampled values zero and one can also be counted, since they go together to make up the total number of bits received. If there is an equal distribution of logical ones and zeros, it is also possible to dispense with the counter 7 summating the logical ones. On the other hand, the counter is required, in order to eliminate

the influence of an unequal distribution of zeros and ones to the greatest extent by forming the quotient of the summated values in the measuring channel and in the working channel.

In a way corresponding to figure 8, the difference between the summated values IE - IV can also be evaluated for a binary state, here the logical one, for

the first sampling stage 1 and the measuring sampling stage 2. This measure has approximately the same effect as that of the circuit indicated in figure 1: the differences between the working channel and the measuring channel are assessed. The difference formation can be combined with the quotient formation. In comparison with figure 6, there is a horizontal shift of the probability distribution function WW. The probability function can again be used to determine the probability density distribution represented in figure 9, which is particularly suitable for the evaluation. Since, however, the two functions can be mathematically transformed into each other, in principle the evaluation of the distribution function is also always possible.

A measuring device allowing a reduction in the measuring time required overall for creating a probability distribution is represented in figure 10. If only one sampling stage with a variable threshold is provided, this threshold must be changed after each measuring interval for a new measurement. If, on the other hand, a plurality of sampling stages 21 to 2n with different threshold values Sv1 - Svn are used, a plurality of measurements can be carried out simultaneously and the total measuring time can be correspondingly reduced. Only little additional hardware expenditure is required for the sampling flipflops and integrators 81 to 8n. The same also applies correspondingly to the measuring arrangement according to figure 1. For reasons of costs, it is not yet economical to create an arrangement with the same number of sampling stages as the number of necessary threshold values. If that were the case, only one measuring interval would be required.

To be able to make statements concerning the signal quality, instead of, or in addition to, changing the

threshold values for the measurements, it is also possible to change the sampling instant of the measuring/sampling stage by means of a phase shifter 16 (figure 4), to which a clock signal LV ahead of the regular clock signal C1 is fed. If this measure is additionally carried out, the entire eye pattern can be acquired on the basis of statistical measurements.

The dependence of the distribution density function in the case of different dispersion values is represented in figure 11. If there is a change in dispersion, the spacing of the maxima of the distribution density function changes. When a transmission system is being installed or optimized, the dispersion is increased or reduced - starting from a value of zero - with the aid of an adjustable dispersion compensator/emulator 15 connected into the signal path. The measurement of the probability distribution and the determination of the spacing ΔS between the maxima of the values for zero and one subsequently takes place in each case. If there are relatively great deviations of the dispersion from the optimum, there is a reduction in the spacings of the maxima for the occurrence of the sampled values assigned to the two binary signal values, both in the case of negative deviations and in the case positive deviations of the dispersion. In dependence on the change in dispersion, given in ps/nm (picoseconds/nanometer), the spacings between the maxima of the distribution density function are given on the y-axis in figure 12. The optimization is carried out by evaluation of the spacing function ΔS. For example, in a way corresponding to figure 12, the falling edges of the measuring curve are extended; their point of intersection determines the optimum dispersion. The measuring curves are again obtained with an arrangement according to figure 1, 4 or 10. Alternatively,... can... [lacuna]

The measuring arrangement for wavelength-division multiplex signals (WDM signals) is represented in figure 13. Part of the binary signal is branched off by an optical coupler 9 and fed via a tunable filter 10 and an optoelectronic transducer 12 to a measuring and evaluation unit 13 as an electrical baseband signal. This unit measures the most important channel parameters, such as channel power, wavelength, signal-

to-noise ratio, but also carries out statistical measurements of the signal quality, as described above, in order for example to be able to make statements concerning the bit error rate, which are transferred to a management system TMN.

The main part of the measuring device is an optical spectrum analyzer, with which main properties such as the level, wavelength and signal-to-noise ratio can be determined. The tunable filter acts as a multiplexing device, to allow the measurements to be carried out with reasonable expenditure. The wavelength of the tuned filter can be set with adequate accuracy with the aid of a calibrating device 11.

A controller 14 undertakes the successive testing of the individual WDM channels with the aid of a channel selection circuit 17. It determines the type of measurement. In the case of statistical measurements, it also determines the duration of the measuring intervals.

Patent claims

1. A method of measuring the signal quality in optical transmission systems, in which an optical binary signal is sampled in a working channel with a first threshold value (Sw) and is additionally sampled in a measuring channel with a second threshold value, then the sampled bits are compared and the comparison values (VD) derived from this are integrated, characterized in that the binary signal (BS) is sampled in the measuring channel during a plurality of measuring intervals, in each case with different threshold values (Sv), in that the summated comparison values (IW) determined by integration of the comparison values (VD) obtained in this way are stored and in that, after an adequate number of measuring intervals with different threshold values (Sv), the distribution function V(s) of the comparison values (VD) is determined as a function of the variable threshold value (Sv).

2. A method of measuring the signal quality in optical transmission systems, in which an optical binary signal (BS) is sampled in a working channel with a first threshold value (Sw) and is sampled in a measuring channel with a second threshold value (Sv), characterized in that the binary signal (BS) is sampled in the measuring channel during a plurality of measuring intervals, in each case with different threshold values (Sv), in that the number of logical zeros and/or ones sampled in the measuring channel during each measuring interval is integrated and is stored as a first summated value (IV), in that the number of bits received during a measuring period is determined or measured and is stored as a summated bit value (IB) and

in that, on the basis of the stored summated values (IV), the probability function (WV(Sv), WW(Sv)) is determined as a function of the variable threshold value (Sv) for the occurrence of a binary state.

3. A method of measuring the signal quality in optical transmission systems, in which an optical binary signal (BS) is sampled in a working channel with a first threshold value (Sw) and is sampled in a measuring channel with a second threshold value (Sv), characterized in that the binary signal (BS) is sampled in the measuring channel during a plurality of measuring intervals, in each case with different threshold values (Sv), in that the number of logical zeros and/or ones sampled in the measuring channel during each measuring interval is integrated and is stored as a first summated value (IV), in that the number of zeros and ones received in the working channel during a measuring period is measured and is stored as a second summated value (IE) and in that, on the basis of the stored summated values (IV, IE), the probability function (WV(Sv), WW(Sv)) is determined as a function of the variable threshold value (Sv) for the occurrence of a binary state.

4. The method as claimed in claim 3, characterized in that, after each measuring interval, the difference between the summated value of the logical zeros of the measuring channel and logical zeros of the working channel or the logical ones of the measuring channel and logical ones of the working channel is formed, in that the difference values are buffer-stored and in that the probability function WD(Sv) is determined from the difference values.

5. The method as claimed in one of claims 2 to 4, characterized in that the probability distribution (WV, WW) is determined, taking into account the second summated values (IE) in the working channel and or the summated value (IB) of the bits respectively assessed during a measuring interval.

6. The method as claimed in one of the preceding claims, characterized in that measuring intervals of different lengths are used.

7. The method as claimed in one of the preceding claims, characterized in that a synchronous sampling of the binary signals (BS) takes place.

8. The method as claimed in one of the preceding claims, characterized in that the sampling takes place in parallel in a plurality of measuring channels with different threshold values (Sv1 to Svn).

9. The method as claimed in claim 8, characterized in that the sampling takes place in parallel in a plurality of measuring channels with different threshold values (Sv1 to Svn) during only one measuring interval.

10. The method as claimed in one of the preceding claims, characterized in that in the measuring channel the sampling instant is changed after each measuring interval.

11. The method as claimed in one of claims 1 to 8, characterized in that the measurements of the probability distributions take place with differently set dispersion values,

in that the measurement results are buffer-stored and in that an at least approximately optimum value for the dispersion compensation is obtained from them.

12. The method as claimed in one of claims 1 to 11, characterized in that the probability density distribution (P(S), PD(S), PI(S)) is determined and criteria for the assessment and/or optimization of the signal quality are derived from it.

13. An arrangement for monitoring the quality of WDM signals, characterized in that a channel selection circuit (10) is provided, with which a WDM channel is in each case selected and fed after optoelectronic conversion to a measuring device (13), in that the main signal parameters are measured and in that the probability distribution of the sampling results is measured in a way corresponding to one of claims 1 to 10.

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

Verfahren und Anordnung zur Messung der Signalqualität in einem optischen Übertragungssystem

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

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Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, fur die Priorität beansprucht wird.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior foreign appplications
Priorität beansprucht

Priority Claimed

19914793.0	Germany	31. März 1999	[X] Yes / Ja	[ ] No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
			[ ] Yes / Ja	[ ] No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
			[ ] Yes / Ja	[ ] No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

German Language Declaration

VERTRETUNGSVOLLMACHT: Als benannter Erfinder beauftrage ich hiermit den nachstehend benannten Patentanwalt (oder die nachstehend benannten Patentanwälte) und/oder Patent-Agenten mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Geschäfte vor dem Patent- und Warenzeichenamt: *(Name und Registrationsnummer anführen)*

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

(14)

And I hereby appoint

Messrs. John D. Simpson (Registration No. 19,842) Lewis T. Steadman (17,074), William C. Stueber (16,453), P. Phillips Connor (19,259), Dennis A. Gross (24,410), Marvin Moody (16,549), Steven H. Noll (28,982), Brett A. Valiquet (27,841), Thomas I. Ross (29,275), Kevin W. Guynn (29,927), Edward A. Lehmann (22,312), James D. Hobart (24,149), Robert M. Barrett (30,142), James Van Santen (16,584), J. Arthur Gross (13,615), Richard J. Schwarz (13,472) and Melvin A. Robinson (31,870), David R. Metzger (32,919), John R. Garrett (27,888) all members of the firm of Hill, Steadman & Simpson, A Professional Corporation.

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410 Rec'd PCT/PTO 01 OCT 2001 09/937878

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UNDER THE PATENT COOPERATION TREATY–CHAPTER II

CHANGE OF ADDRESS OF APPLICANTS' REPRESENTATIVE

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ATTORNEY DOCKET NO.:	P01,0284
INTERNATIONAL APPLICATION NO:	PCT/DE00/00608
INTERNATIONAL FILING DATE:	01 MARCH 2000
INVENTION:	METHOD AND ARRANGEMENT FOR MEASURING DISTRIBUTION FUNCTIONS FOR DETERMINING THE SIGNAL QUALITY IN OPTICAL TRANSMISSION SYSTEMS

Assistant Commissioner for Patents,
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